FERMILAB-TM-2551-DI
December 2012

Accelerator/Experiment Operations - FY 2012

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This Technical Memorandum (TM) summarizes the Fermilab accelerator and accelerator experiment operations for FY 2012. It is one of a series of annual publications intended to gather information in one place. In this case, the information concerns the FY 2012 MINOS and MINERνA experiments using the Main Injector Neutrino Beam (NuMI), the MiniBooNE experiment running in the Booster Neutrino Beam (BNB), and the Meson Test Beam (MTest) activities in the 120 GeV external Switchyard beam (SY120).

Each section was prepared by the relevant authors, and was somewhat edited for inclusion in this summary.

<u>Accelerator Operations</u> (R. Dixon, S. Henderson)

FY 2012 Neutrino Operations

The low-energy and high-energy neutrino beams ran steadily until May 1, 2012 when the accelerators were shutdown to begin work on the Accelerator Neutrino Upgrade (ANU) necessary to increase the proton intensity for NOvA, and for maintenance work. The NuMI target failures that had plagued neutrino beam operations in 2011 were completely absent in the 2012 running. Target NT07 was installed in late October, 2011. It had been modified to mitigate the weaknesses in the earlier targets. NT07 experienced no problems before the accelerator complex was shutdown for the ANU. The only significant downtime during the period from October 1 to May 1 occurred at the end of January when a Main Injector quadrupole had to be replaced due to an internal water leak. During this period 4.5 x 10^{20} protons were accelerated through the 8 GeV Booster operate both neutrino beams, the SeaQuest beam, and the Test Beam. Fig. 1 shows the total beam integrated through the 8 GeV Booster for the fixed target beams, and Fig. 2 summarizes the protons delivered to the NuMI target.

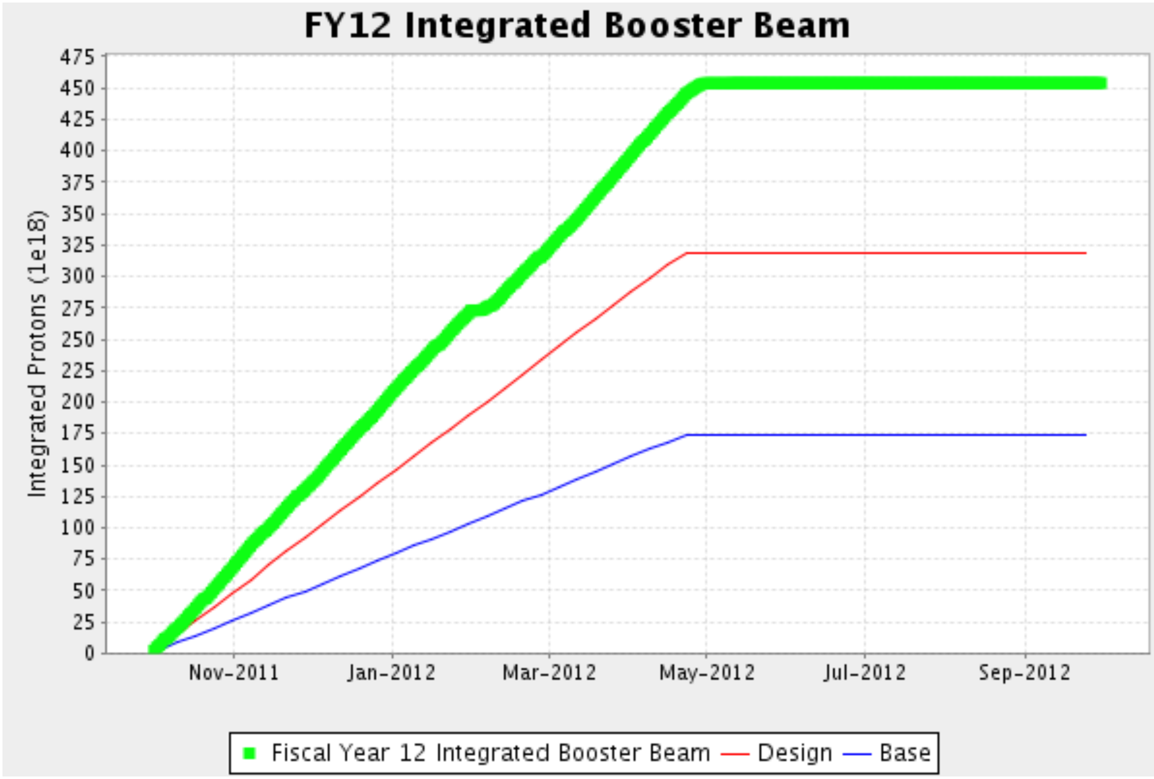

Figure 1: Fiscal Year 2011 integrated proton beam delivered from the Booster.

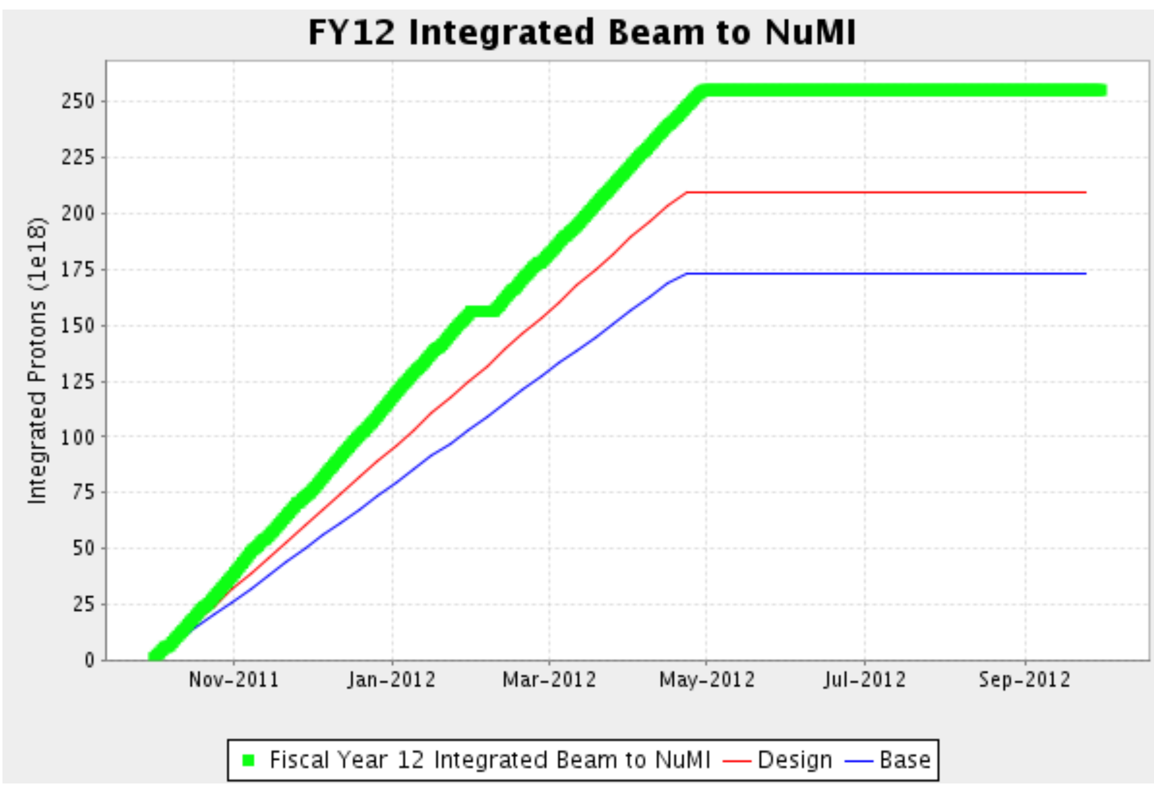

Figure 2: Fiscal year 2012 integrated proton beam to NuMI.

MiniBooNE ran without major problems during FY 2012. The most significant downtime was for the Main Injector quadrupole repair at the end of January. Fig. 3 summarizes the Booster neutrino running.

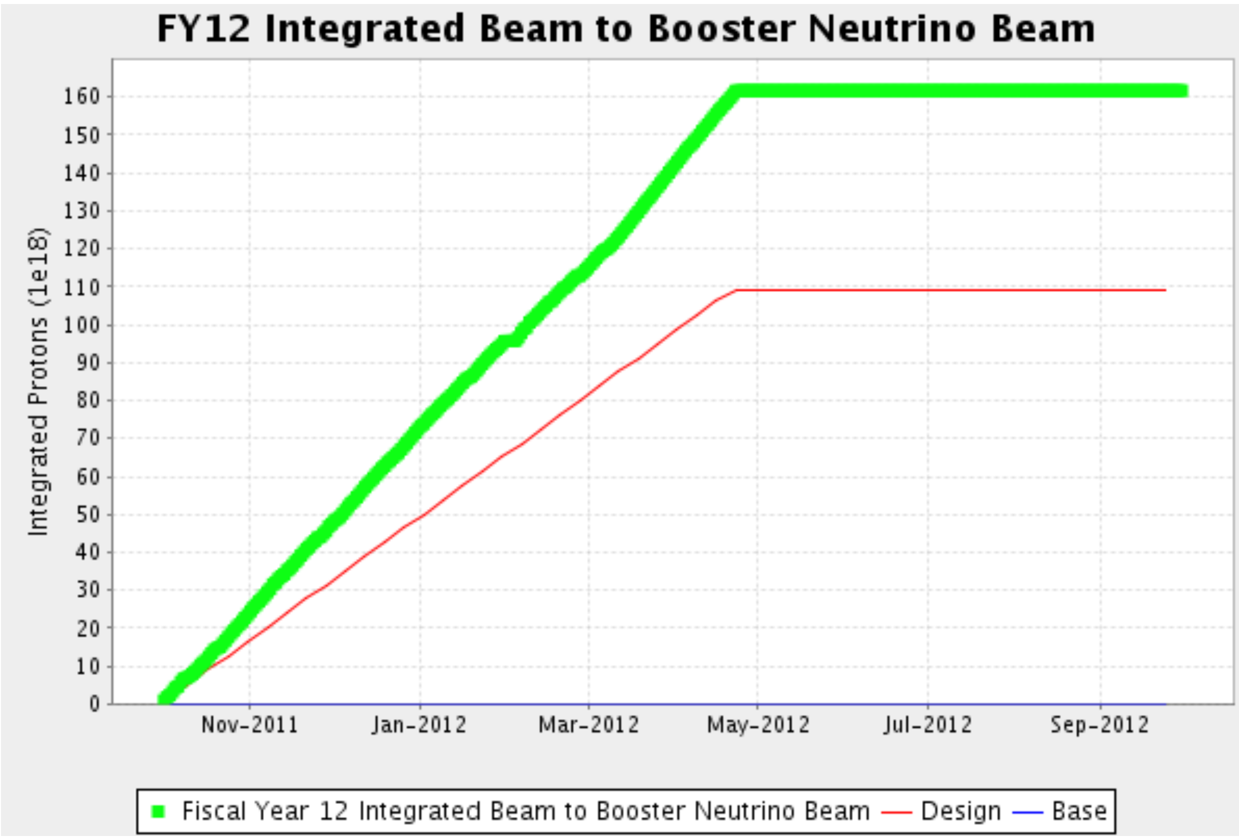

Figure 3: Fiscal year 2012 integrated proton beam to MiniBooNE.

NuMI Beam and MINOS Operations (S. Hahn, B. Pahlka, R. Plunkett)

Unlike the case of FY 2011, where several different running conditions and target water leaks resulted in several downtimes, FY 2012 only had one running condition— low energy (LE10) with the horn current in the forward direction (neutrino mode)—and only one planned downtime in January. Running terminated at midnight on April 30, 2012 for the extended shutdown for the remainder of the fiscal year, mainly for NOvA construction and accelerator improvements. This marked the end of the MINOS run, which had started May 2, 2005, during which time a total of 15.7 x 10^{20} protons on target was delivered to the NUMI target. The extended shutdown is important to MINOS+ (extended MINOS running for 5 more years) because during this time MINOS+ will refurbish the near detector DAQ to make the DAQ system more robust, and to provide spares for the far detector.

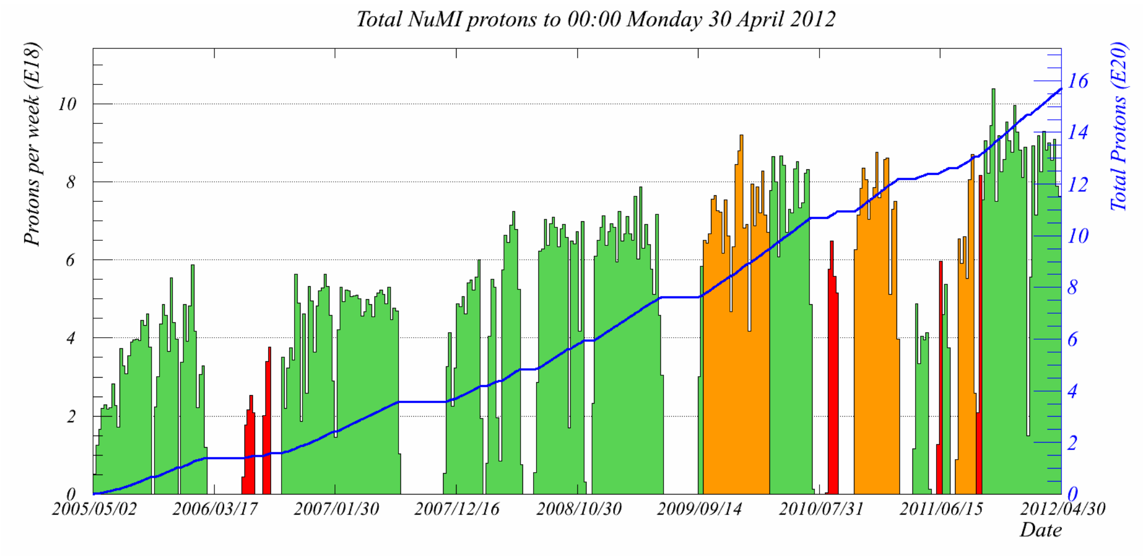

Figure 4a: Protons delivered to the target of the NUMI beamline during the MINOS run. Total protons on target during this period was 15.7×10^{20}.

During FY 2012, the efficiency both at the near and far detectors was mostly very good, usually above 95%. However, some problems were encountered during the running period. During October, several crate power supplies had to have aging electrolytic capacitors replaced at the far detector, and the near detector experienced some processing problems due to a planned network outage. Also, the far detector experienced a magnet trip traced to some bad relays in the magnet power supply, and the near detector had a bad PC power supply which affected both that PC and the readout processor (ROP) connected to it. In November, MINOS had detector trips on high temperature and more ROP failures. The far detector had a problem in one crate due to a faulty fuse on the AC input, and at the same time a bad PC power supply. To deal with the temperature problems at the near detector, a new chilled water system was installed and brought online in January; unfortunately, water loss in this new system during a filter change caused both electronics rack trips and near detector magnet trips. In the latter half of January, the work to measure the time of flight (TOF) of MINOS neutrinos began, starting with the installation of equipment both at the MINOS detector and upstairs in the surface building (as well as other locations in the beamlines leading to NUMI tunnel). During the short scheduled shutdown at the end of January, this TOF work was expanded with the addition of more electrical circuits at the near detector and equipment at the far detector. By the end of February, a large portion of the TOF instrumentation was being read out and monitored. At the start of March, another bad supply died in a far detector PC. Eventually, all PC power supplies were replaced at both the near and far detectors (300 W to 450 W). Cooling water problems were also encountered at the far detector leading to replacing the cooling water system there, also. Later in March, data logging problems eventually traced to bad clock chips in accelerator front-end computers. On April 9, power to a Soudan chiller was lost during a snowfall, and thus the far detector magnet had to shut off for about 8 hours. On average, the near detector was live 92.6% of the time beam was delivered and 94.2% of protons on target were used; the far detector was live 95.6% and 95.1% of protons on target were used.

On April 30, the extended shutdown began in earnest, though preparations had been proceeding since the latter half of 2011. MINOS decided to keep taking cosmic data as much as possible so as to find and fix problems as they occurred in the existing DAQ system. Also, for most of this running period, both the near and far detector magnets were off to save energy.

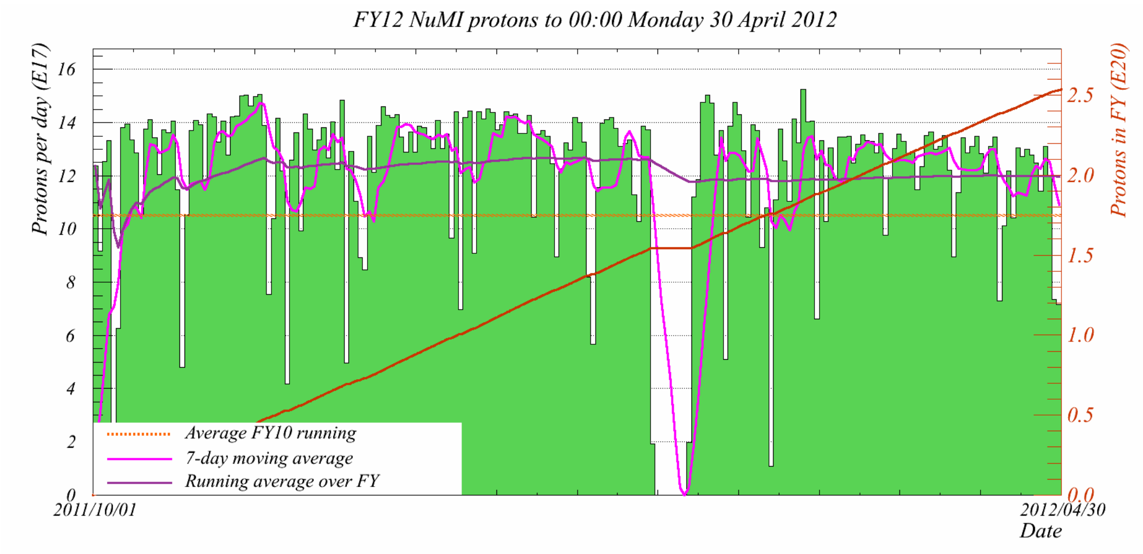

Figure 4b: Protons delivered to the target of the NUMI beamline during Fiscal 2012. Total protons on target for FY 2012 were 2.54×10^{20}.

The following is a list of work on both the near and far detectors performed both in anticipation of and during the extended shutdown:

- The NUMI target hall was completely re-engineered so as to make target and horn running configuration changes much easier, safer, and more efficient.
- Both the near and far detector magnets have been inspected and tested.
- A new chiller is being installed at the far detector.
- The test crate which had formerly been in the MINOS surface building was moved to the D0 computer room; testing of both the “DAQ refurbishment” and old readout processors is now much easier.
- An inventory of existing spares and plans for making more of the components with the least spares was generated.
- All front-end DAQ racks had their filters and racks cleaned and Wiener power supplies inspected and tested.
- A new rack for the “DAQ refurbishment” was added (along with three additional racks for MINOS TOF and NOvA). This new rack went through several redesigns to meet the ES&H underground fire safety requirements, including:
    - Electrician work was done to extend the wireway above the new racks so as to

provide adequate power for the new DAQ racks and the other racks. Also, new lighting was added that makes work much easier.

- o All cables inside this rack and from this rack to the front-end racks are plenum-rated for fire safety except AC power cables (which were approved by ES&H).
- o Airflow as determined by the 1U 8-core processor unit fans is from the front of the rack to the rear of the rack. The front of the rack is sealed with multiple filters so that all input air is filtered so as to alleviate the build-up of dust from the environment.
- o The rack will have an approved rack protection system which will shut down rack power in case of fire.

- Gigabit Ethernet, serial, and reset cables have been run to each of the Master crates. In addition, an MVME 5500 has been added to each of these crates. These MVMEs, which are standard across the laboratory, will replace the RIO3s currently being used.

- New 1U Koi 8 core processors in the new rack replace the many CPUs currently used for the DAQ, as well as the gateway computer and the local computer used for debugging in the NUMI tunnel. There are two dedicated processors for the latter, and 8 processors for the DAQ. The estimate is 2-4 of these will be needed for normal running; the remainders are spares.

- Testing in the D0 test stand has allowed the PPD/EED/Online Support Group to get all of the system up and running except for actual data-taking. Currently, the DAQ produces correctly formatted but empty root files.

All this work was constrained by multiple power outages for local electrical work and work associated with the NOvA construction. Also, restrictions associated with the NOvA off-axis hall construction resulted in limited access and caused detector HV to be left off for extended periods to avoid damage to the PMTs from vibrations, which can be measured with seismometers and water level systems installed in the NUMI tunnel, as well as geometers installed on the Minerva detector.

In FY 2012, the very successful operations of the NuMI program were reflected in physics results from the MINOS experiment which took advantage of the full dataset delivered in both neutrino and anti-neutrino enhanced beams, as well as a very significant sample of events induced by cosmic rays. Three significant foci of the experiment were combined analysis of the charge-current samples, comparisons of neutrinos and antineutrino oscillations, and studies of the appearance of electron neutrinos which depends on the smallest of the mixing angles, θ_{13}.

Figure 5 shows the confidence contours established by MINOS from the combined analysis of 10.7 x 10^{20} POT of neutrino-enhanced beam and 3.36 x 10^{20} antineutrino-enhanced, together with the atmospheric event sample. The result shows a best value for the effective mixing angle which differs from $\pi/2$. These preliminary results are currently being prepared for publication. A separate and consistent analysis of the full atmospheric dataset has appeared as Phys. Rev. **D6** 052007 (2012).

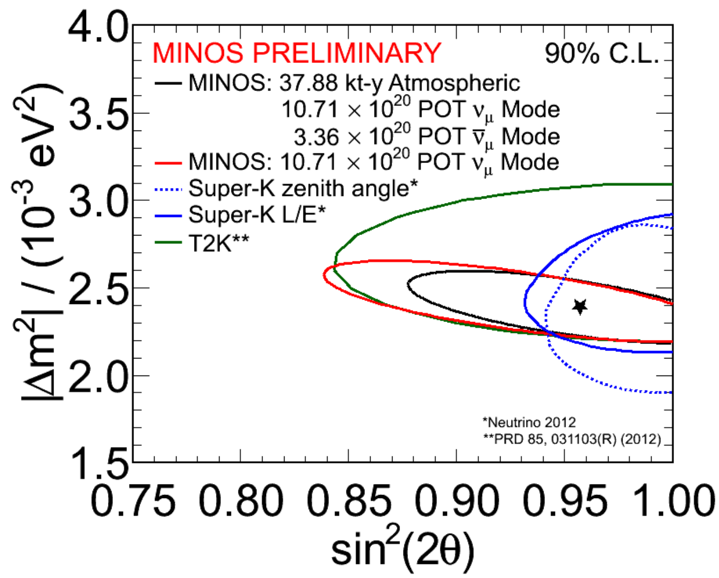

Figure 5: 90% confidence limits around MINOS best fit values for the oscillation parameters of muon neutrinos and antineutrinos. Results from running with the NuMI beam are combined with results from atmospheric events collected with the MINOS far detector. Results are compared to other world experiments.

A second major result from MINOS in FY 2012 was an improved and expanded search for electron neutrino appearance. This result, difficult in a steel calorimeter, was carried out with sophisticated pattern matching algorithms and statistical discrimination. The result, show in Fig. 6 for all the cases, excludes zero effect at the >95% confidence level. The central value of $\sin^2\theta_{13}$, assuming normal hierarchy and $\delta_{cp}= 0$, is 0.05, somewhat lower than that obtained by reactor experiments.

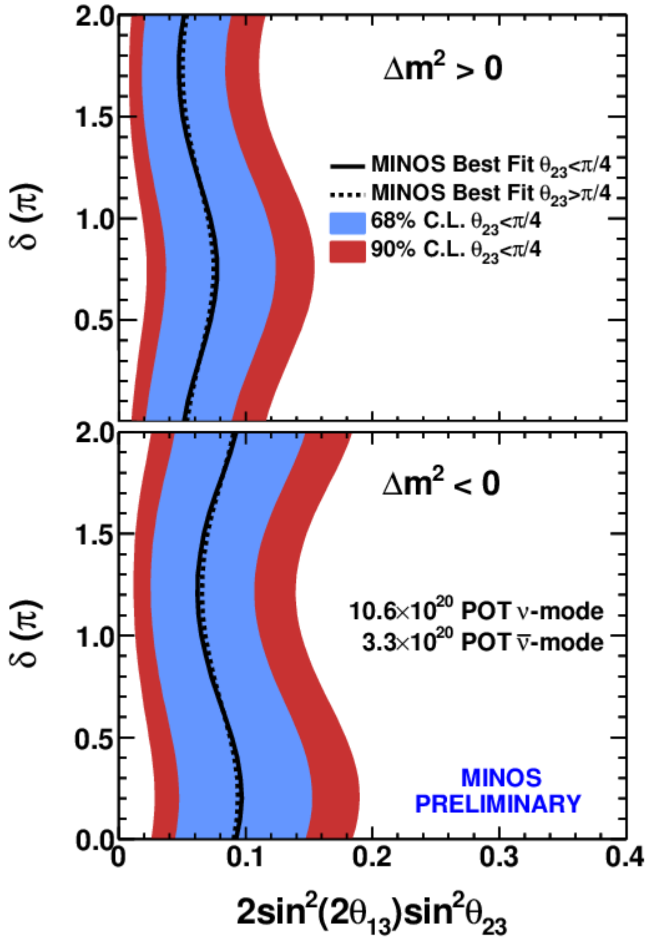

Figure 6: MINOS results on the appearance of electron neutrinos in the NuMI beam. The results vary with assumptions concerning the mass hierarchy of the neutrino mass states and the possible CP-violating phase δ in the PMNS mixing matrix.

As reported last year increased datataking had given consistent results for the oscillations of neutrinos and antineutrinos. Final analysis of this work appeared in FY 2012 as PRL **108** 191801 (2012). Further antineutrino datataking was added to the analysis in FY 2012, resulting in the contours displayed in Fig. 7, which compares the key oscillation parameter δm^2 for the neutrino and antineutrino oscillations, using the complete antineutrino sample obtained from 3.36 x 10^{20} POT in the NuMI beam. Publication of this result is in preparation. MINOS also published, with larger errors, results from the small component of antineutrinos in the neutrino beam, as Phys. Rev. **D84** 071103 (2011).

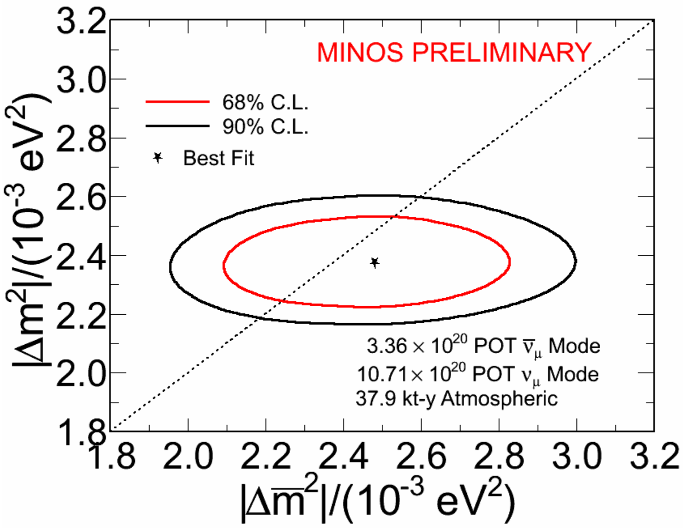

Figure 7: Comparison of the oscillation parameter Δm^2 for muon neutrinos and antineutrinos, using all collected MINOS NuMI beam and atmospheric data. The resulting mass difference is consistent as expected from CPT symmetry.

Other studies from MINOS in FY 2012 included further studies of fundamental symmetries. A search for Lorentz invariance and CPT with antineutrinos in the near detector appeared as Phys. Rev. **D85** 031101, (2012). A particular event of the year was a measurement, using upgraded timing equipment, of the neutrino time of flight over 735 km, which yielded results consistent with the speed of light c, with a systematic error of 29 ns. Sufficient data and calibrations were taken in FY 2012 to yield an expectation that a fall 2013 result will have a systematic error of < 3 ns, a tenfold improvement.

E-938 / MINERνA (D. Harris, K. McFarland)

MINERνA Construction and Installation Activities in FY 2012

The MINERνA experiment began taking data on the partially completed detector in November 2009 while the last components were being built and commissioned. By mid-March 2010 the installation was completed and the experiment switched over to a new data acquisition system and started taking data with the full active detector, and all of the solid targets installed. By the beginning of FY 2012 the cryogenic target was filled with Helium, and the veto wall upstream of that target was fully commissioned and operational. This wall, which is used to ensure that events do not originate from upstream neutrino interactions, consists of two planes of scintillator panels extending roughly 15' tall by 10' wide, placed downstream of a 1" and 2" thick plane of steel, respectively. In FY 2011 the experiment, with the help of the Fermilab PPD, also completed the design and fabrication of a new Kevlar and steel-based water target. This target uses two steel rings and a spacer ring, and Kevlar and vapor barriers are stretched between the rings. Water is added through a penetration in the spacer ring. The water target was installed and filled in mid-November 2011, and the first full water target data were taken November 18.

Because the MINERvA data analyses depend critically on the MINOS near detector being operational, MINERvA personnel involvement remained high in FY 2012. MINERvA collaborators are part of the detector expert crew that addresses MINOS near detector electronics and DAQ problems, along with MINOS and PPD personnel. MINERvA also helped manage the program of work done by personnel in PPD to refurbish the MINOS DAQ. The refurbished DAQ takes advantage of components (PC's and processors) that are retired after the shutdown of the TeVatron and the decommissioning of the CDF and D0 detectors.

One upgrade that occurred over FY 2012 is the approval of an additional institution to staff remote shifts for the MINERvA experiment. The necessary hardware infrastructure was developed in early 2011 at the University of Rochester, duplicated and sent to several remote institutions based on interest and need, and by April 2011 the University of Rochester had completed the necessary tests to be certified as a remote shift location. By the end of FY 2011 there were four remote sites qualified: University of Rochester, Tufts University, University of Texas at Austin, and the University of Santa Maria in Valparaiso, Chile. In FY 2012 Tufts qualified as well to staff remote shifts. By the end of the Low Energy run in April 2012 the experiment was running approximately 40% of its shifts remotely.

Finally, in preparation for the long shutdown in FY 2012 and the excavation of the NOvA Near Detector Cavern, PPD personnel designed, built, and installed a roof to protect the MINERvA detector. This roof provides a barrier not only for falling debris from the roof but also water. The detector was also equipped with vibration monitors, which were used to determine whether or not it would be safe to turn the high voltage on the phototubes during the excavation. The excavation, which started in FY 2012, did cause vibrations high enough to endanger phototubes if high voltage had been applied. The detector functionality itself was monitored during the accelerator shutdown by turning on the high voltage and taking calibration data during the two scheduled hours in the day when there was to be no excavation done.

Physics Goals for MINERνA in Low Energy Beam

The goal during the low-energy neutrino running is to provide exclusive cross-section measurements on a variety of nuclei. The data will help in understanding the details of neutrino interactions. Low energy events tend to have few final state particles – which allows the MINERνA detector to identify single particles and the exclusive channels important for current and future oscillation experiments. MINERνA's detector is about a factor of 10 more fine-grained than the NOνA detector, and can identify processes that will contribute backgrounds to NOνA. MINERνA sees a higher neutrino beam energy than T2K's near detector, and measures reactions that contribute backgrounds to T2K from the high-energy tail of the beam (where "high energy" in the T2K case means above 1 GeV). Low energy data will also allow a study of exclusive channels as a function of target nucleus. Various processes are expected to have different nuclear dependencies, which in turn can modify the measured neutrino energy compared to the initial neutrino energy. MINERνA should be able to see those different dependencies clearly if they are at the 5-10 per cent level, as they are in charged lepton scattering.

Time Line of MINERνA Operations

MINERνA started taking physics-quality data with its partially completed detector in November 2009. For this detector, the entire downstream hadron and electromagnetic calorimeters were installed, as well as about half the active target modules. Between November and January there was also one nuclear target containing both iron and lead, and a veto region before the active tracker volume, allowing first nuclear target studies with antineutrinos. After January the nuclear target and veto region were removed to continue installation of the remaining 45% of the detector. During the second installation period, from January 2010 through March 2010, the downstream detector components remained in a stable configuration and the experiment continued to take antineutrino data.

Between the start of the MINERνA anti neutrino run until March 1, 2010, the ArgoNeuT Liquid Argon TPC test was located between the MINERνA detector and the MINOS near detector. This represented about 2 metric tons of passive material in a complicated geometry that intersect approximately 40% of the muons that start from the fiducial region of MINERνA and pass into the MINOS near detector. The average energy loss passing through ArgoNeuT was about 100MeV, but the variation of the energy loss is large from event to event, and in some regions up to a GeV of energy would be lost between MINOS and MINERνA. ArgoNeuT was removed from between the two detectors on March 1, 2010. During FY 2011 MINERνA developed the necessary detailed Geant-based simulation to correctly simulate on an event-by-event basis the energy loss that will occur for the muons crossing through the region.

On March 22, 2010 the detector installation and checkout was completed and the neutrino running began. This run includes all of the solid nuclear targets that are planned for the experiment. The livetimes quickly reached the 95% level and above after about a week of running, and have been stable and high since that time. Over the entire Low Energy run (March 22, 2010 through April 26, 2012) the integrated livetime of MINERνA was 97.1%, and the FY 2012 livetime was 97.7%. .

The data taken in FY 2012 was primarily Low Energy neutrino data on a single target. Between October 6, 2011 and April 26, 2012, the experiment received 2.49×10^{20} POT, roughly 50% of the total request of 4.9×10^{20} POT over the last 5 months of our 26 month Low Energy run. The number of integrated protons on target in both the neutrino and anti-neutrino running modes is shown in Table I.

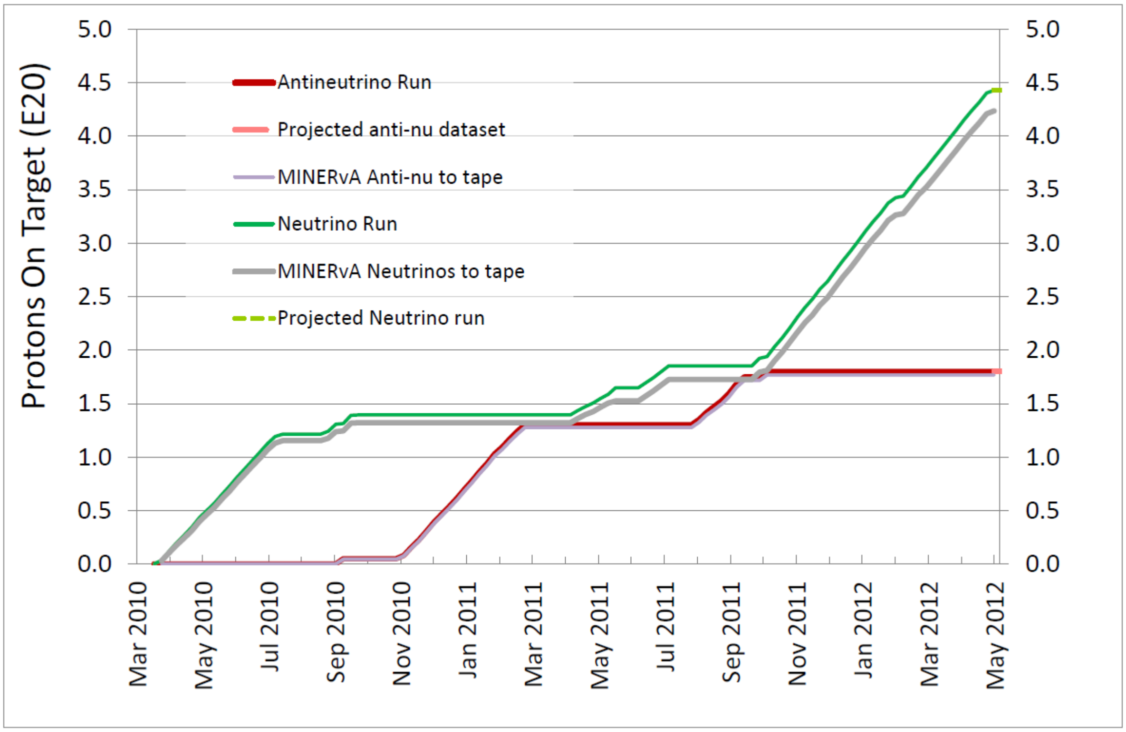

Figure 8: Recent NuMI running, the MINERvA data written to tape. The red line shows the run that doubled the MINOS pre-March 2010 anti-neutrino exposure. The green line shows the run following the anti neutrino run that eventually gave MINERvA 90% of its full requested low-energy neutrino exposure. The grey line represents the protons on target for those spills that were written to tape (and only accounts for the livetime of the MINERvA detector, not both MINOS and MINERvA).

Table I: Normal and special runs for the low-energy-target running, as well as the protons recorded in each configuration through the entire Low Energy Run..

Run	**Dates**	**POT Recorded**	**Goal**
Target at 100cm, Forward Horn Current 200kAmps	8/26/10 - 9/3/10 and 9/24/11-9/29/11	7.0×10^{18} and 7.0×10^{18}	15×10^{18}
Target at 100cm, Reverse Horn Current 200kAmps	9/3/10 - 9/8/10 and 9/30/11-10/4/11	4.1×10^{18} and 5.5×10^{18}	0
Target at 150cm, Forward Horn Current 200kAmps	-	0	15×10^{18}
Target at 250cm, Forward Horn Current 200kAmps	9/8/10 - 9/17/10 and 6/11/11 – 6/20/11	7.7×10^{18} and 8.1×10^{18}	15×10^{18}
Target at 10cm, Forward Horn Current 200kAmps	-	0	15×10^{18}
Target at 10cm, Forward Horn Current 150kAmps	-	0	15×10^{18}
Target at 10cm, 0kAmps, MINOS coil focusing negative muons	4/14/11-4/21/11	7.2×10^{18}	15×10^{18}
Target at 10cm, Forward Horn Current, 180kAmps (nominal low-energy running)	3/21/10 through 4/26/12	398×10^{18}	400×10^{18}

<u>E-944 / MiniBooNE</u> (R. Van de Water)

The FY 2012 Booster Neutrino Beam running for MiniBooNE was entirely in antineutrino mode. During this shortened period, which ended April 2012 for the accelerator complex shutdown, MiniBooNE collected data from 1.40×10^{20} protons on target (POT). Added to previous antineutrino running, this brought MiniBooNE to a total of 1.16×10^{21} POT in antineutrino mode. This is almost twice the antineutrino data set used for oscillation results with 5.66×10^{20} that were published in Phys. Rev. Lett. **105**:181801 (2010). Our stated goal of our request in 2010 to extend the antineutrino run was to double our data set, which we have accomplished. Figure 9 shows the latest oscillation analysis with $1.13\text{x}10^{21}$ POT (left). The analysis POT is slightly less than the collected POT due to data quality cuts. This new result suggests that in antineutrino mode MiniBooNE data are consistent with the earlier LSND results at the 99% level. The excess of oscillation events in antineutrino mode is 78.4 +/- 28.5 events in the energy range $200 < E_{QE} < 1250$ MeV. The right plot in Fig. 9 shows the results of combining both neutrino and antineutrino oscillation data sets, which is even more significant than the antineutrino result only. The combined oscillation excess is 240.3 +/- 62.0 events. Clearly there is a 3.8σ excess of electron like events over background that is consistent with two neutrino oscillations, but not conclusive. Further studies will be required to finally understand the source of the anomaly.

Figure 10 shows the integrated performance of the Booster Neutrino Beam up to April of FY 2012. The performance of the Booster during FY 2012 was steady, with beam uptime of 85% and average weekly delivered protons of 0.50×10^{19} protons on target/week. The weekly protons-on-target steady climb in FY 2012 due to improved Booster performance and Tevatron shutdown. Also shown are various projections for three proton/hour delivery rates. For all of FY 2012 we easily beat our most optimistic projection of 3.0×10^{16} protons/hr. This excellent running allowed us to get very close to our analysis goal of about 1.20×10^{21} by the scheduled 2012 shutdown.

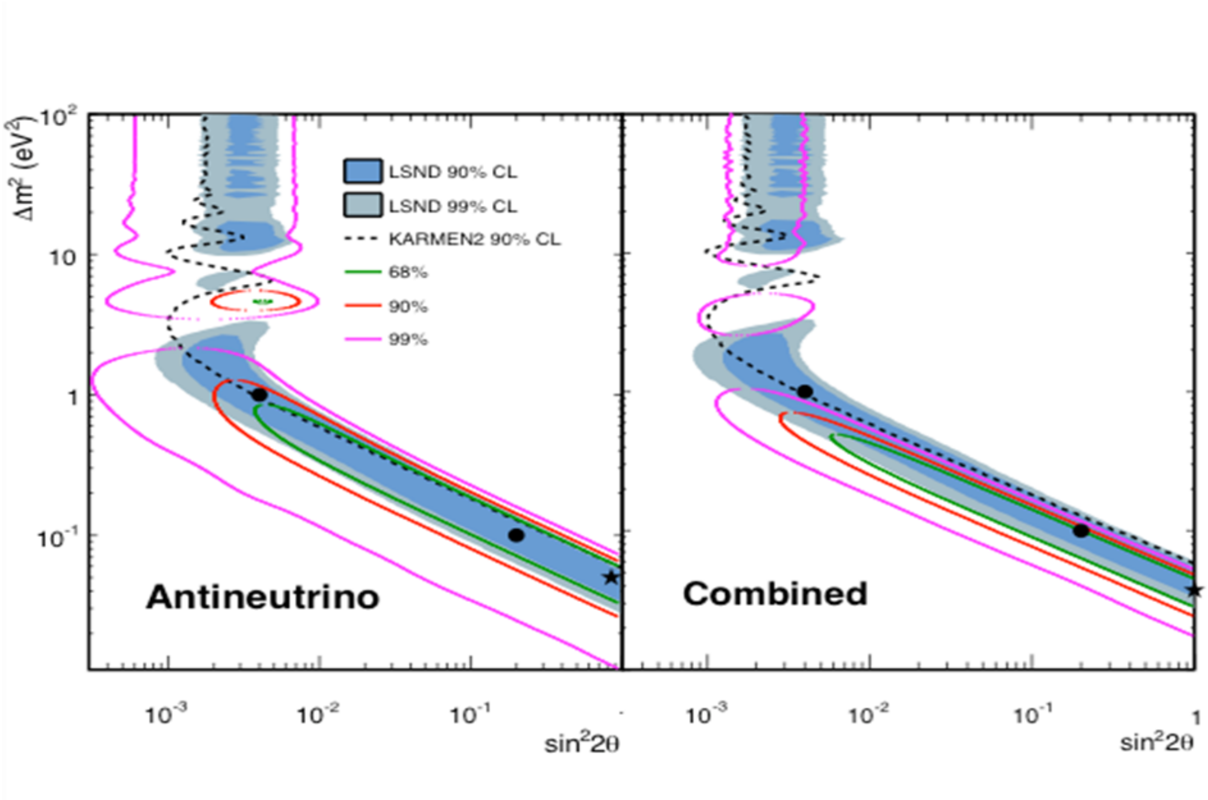

Figure 9: MiniBooNE 68%, 90%, and 99% C.L. allowed regions within a two neutrino oscillation model from 1.13×10^{21} POT antineutrino mode (left), and combine total neutrino and antineutrino data sets (right) for events with $200 < E_{QE} < 1250$ MeV. The black star shows the best fit point.

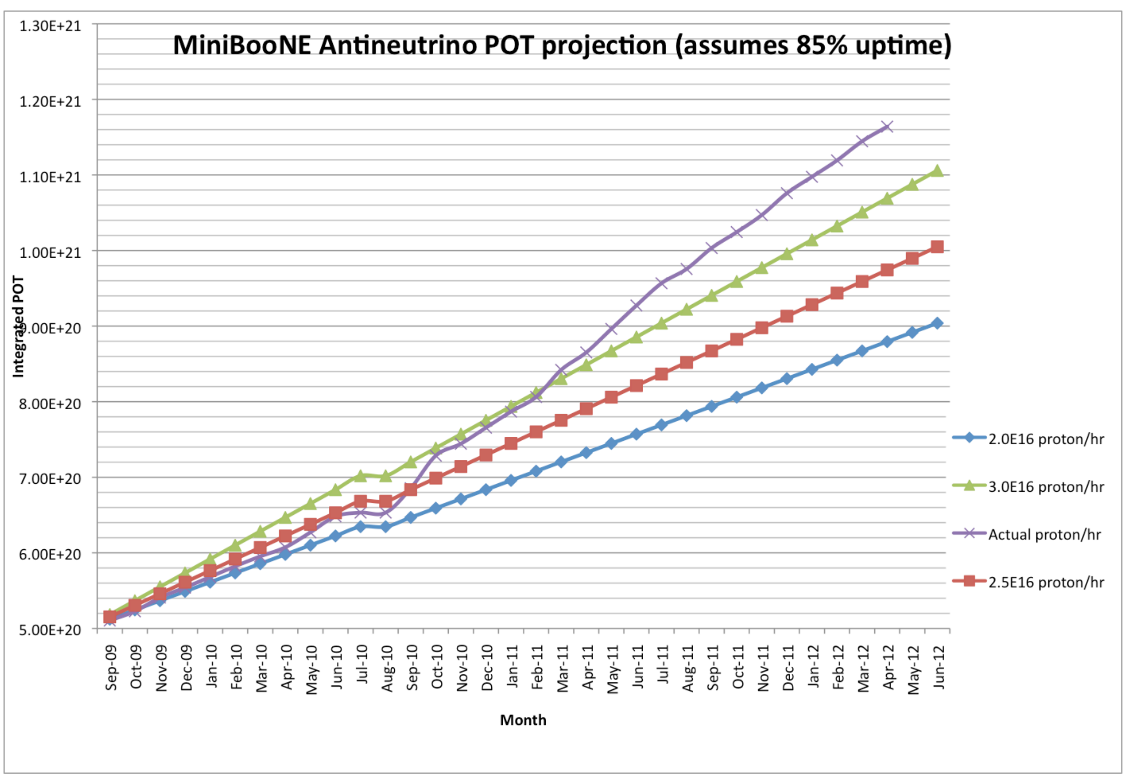

Figure 10: MiniBooNE actual integrated POT and projection for various beam rates. At the end of April FY 2012 a total of 1.16×10^{21} POT had been delivered in antineutrino mode.

An important aspect of continued running of MiniBooNE is the reliability of the beamline and horn. For the FY 2012 antineutrino run period, the combined beamline and detector uptime was over 85%. The most crucial element, the horn, operated for over 390 million pulses, surpassing the first horn, which failed seven years ago with 94 million pulses. Both these numbers were world records at the respective times. In the unfortunate event of complete failure, a spare horn and target are available. It would require four to six weeks to install the replacement system.

Finally, the stability of the beamline and detector is demonstrated in Fig. 11 which shows the number of neutrinos/POT. Aside from a short period with a beamline absorber problem in early 2006, the neutrino/POT rates have been constant to within 2%.

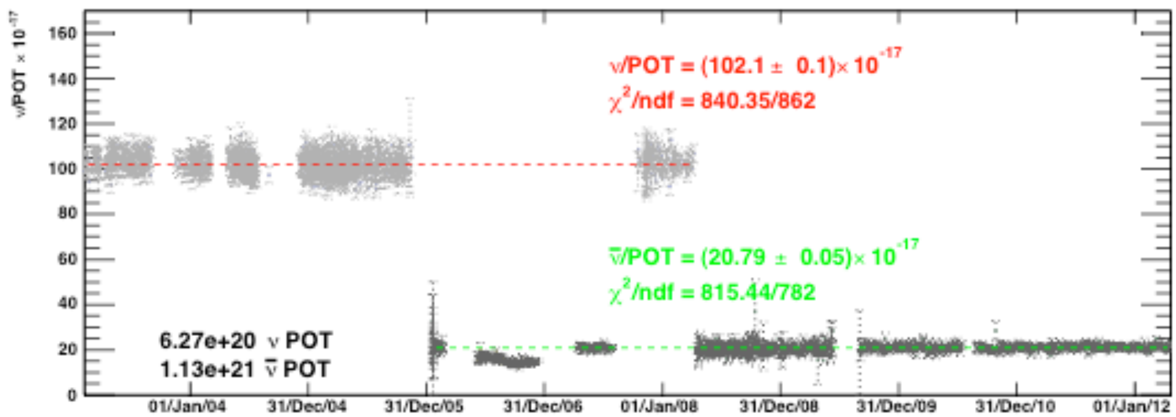

Figure 11. Neutrinos/POT for both neutrino and antineutrino running. The overall stability is excellent as shown by the χ^2/ndf near one. The antineutrino mode does not include the absorber problem data in early 2006. The factor-of-five difference between neutrino and antineutrino modes is due to the reduced flux and cross section which makes taking high statistics antineutrino data samples difficult and time consuming.

FIXED – Target Switchyard 120 GeV (SY120) and MTest (A. K. Soha, C. Moore, M. Geelhoed)

Neutrino Muon Bermpipe Issue

The Neutrino Muon beamline was one of the last beamlines to run during 800 GeV slow spills. During its last run while providing beam to KTeV, the beamline ran at 150 GeV/c protons. Converting this beamline to Main Injector's slow spill running of 120 GeV/c was possible.

In February 2011, vacuum readings of the underground bermpipe from enclosures G2 to NM1, showed signs that vacuum was degrading in the pipe. Based on construction drawings, this pipe mainly consisted of 16" pipe and three sections of 30" pipe called transitions. These transitions ranged from 60 feet to 40 feet long. Figure 12 shows the profile view of the bermpipe.

Further investigation with video inspection revealed a third flange located halfway down the pipe.

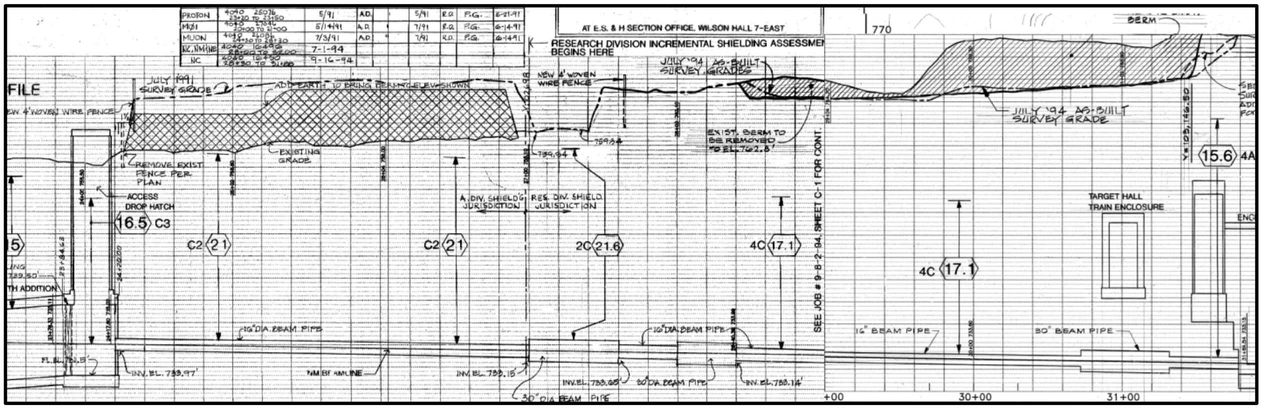

Figure 12: G2 to NM1 Bermpipe with three transitions.

The final plan was to sleeve the existing pipe using an outside contractor with a steel pipe, and to fill the transitions with a material to keep water away from the surface of the sleeved pipe. In December 2011, the operation to begin filling the transitions began. The first attempt was in the first transition with a special mixture of grout. During the operation the injection hose flipped directions and grout mistakenly was poured into the 16” pipe. This blockage was occluding the bottom half of the pipe. Once the grout hardened, the plans changed from grout application to grout removal. Grout removal started with different methods, the best productive method was using a rod pushing machine with a shovel attachment. Once the process got to the transition, the machine was able to push the grout in the bermpipe.

Neutrino Muon Commissioning for E-906 SeaQuest

In February 2012, all of the effected enclosures were reassembled using a specific layout bending the beam around the grout. With all necessary approvals, beam operations began on March 6th 2012. On March 7th 2012 the E-906 shifter reported the detector saw 10,000 muons per pulse. Later in that night on March 8th 2012 the first beam profile was seen on the target SWIC. On March 14th 2012, standard beam profiles looked like Fig. 13. In the 34 days that the experiment had before the 2012 shutdown, E-906 received just over 68,000 pulses of beam ranging in intensities, maximum being 1.18×10^{12} and a total of 1.42×10^{16} POT.

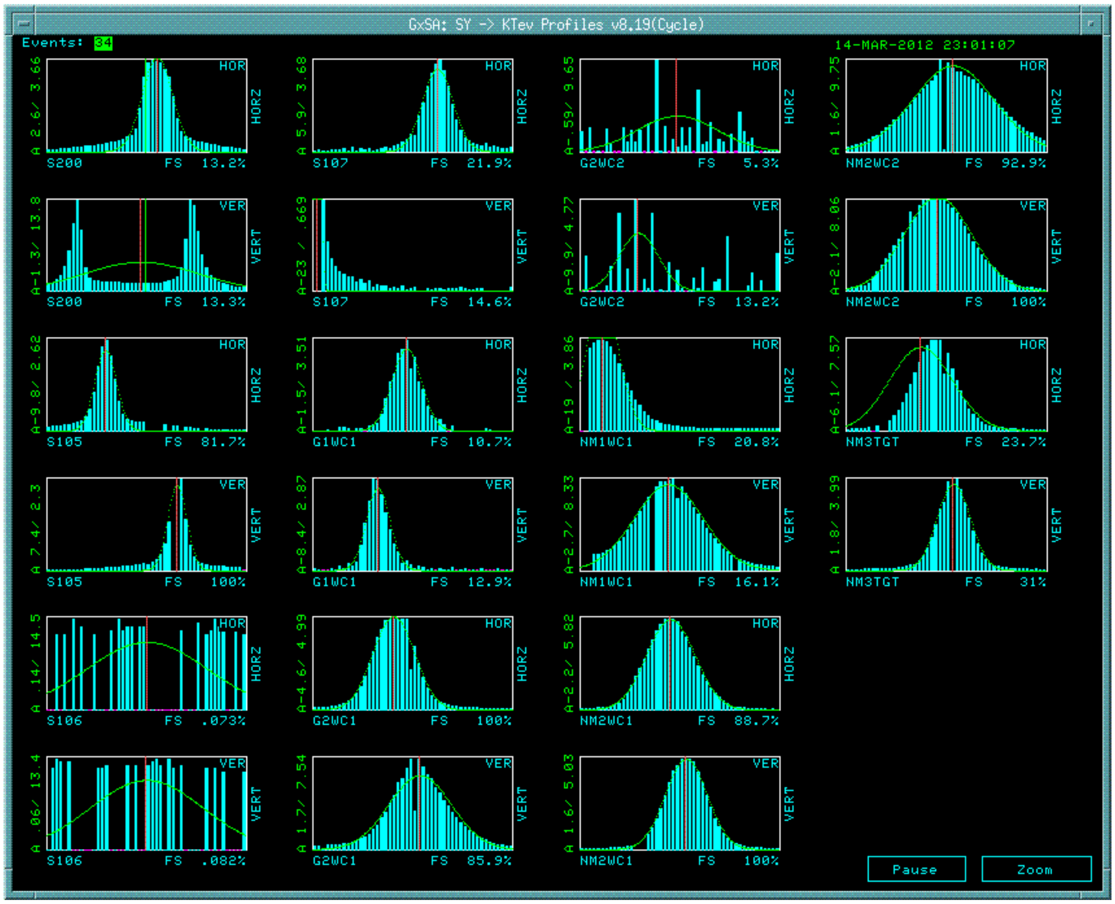

Figure 13: Beam profile for the Neutrino Muon beamline.

Neutrino Muon Bermpipe Grout Removal

During the 2012 shutdown grout removal efforts were restarted in the berm pipe. AD Mechanical support developed with two companies a tethered control grout removing robot, Igorr. Igorr was equipped with two articulating arms and able to travel down the bermpipe. Once at the face of the grout Igorr used a high pressure water jetting rod that was capable of blasting away grout. Fig. 14 is the design drawing of Igorr. The white ball on top of Igorr was a frontward facing camera. The operator was able to control Igorr from this view as shown in Fig. 15. Grout removal started on July 13th and completed on August 6th. On September 4th over 650 gallons of water was vacuumed out of the first and third transitions, the remaining amount of water is being pulled out by vacuum pumps.

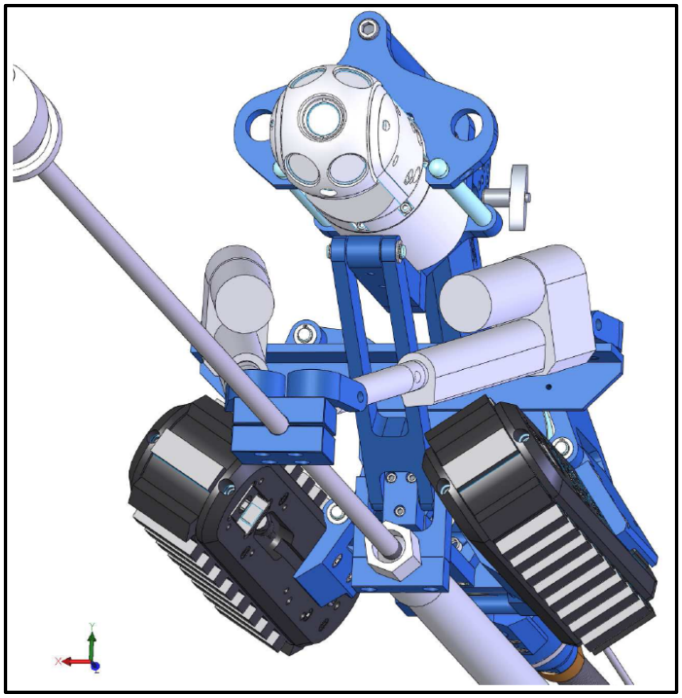

Figure 14: Igorr with articulating arms and high pressure water rod.

Figure 15: View from Igorr's on board camera.

The Fermilab Test Beam Facility

The Fermilab Test Beam Facility (FTBF) gives users from around the world an opportunity to set up their particle detectors in a variety of particle-beams. A plan view of the facility is shown in Fig. 16. The web-site URL for the facility is www-ppd.fnal.gov/FTBF.

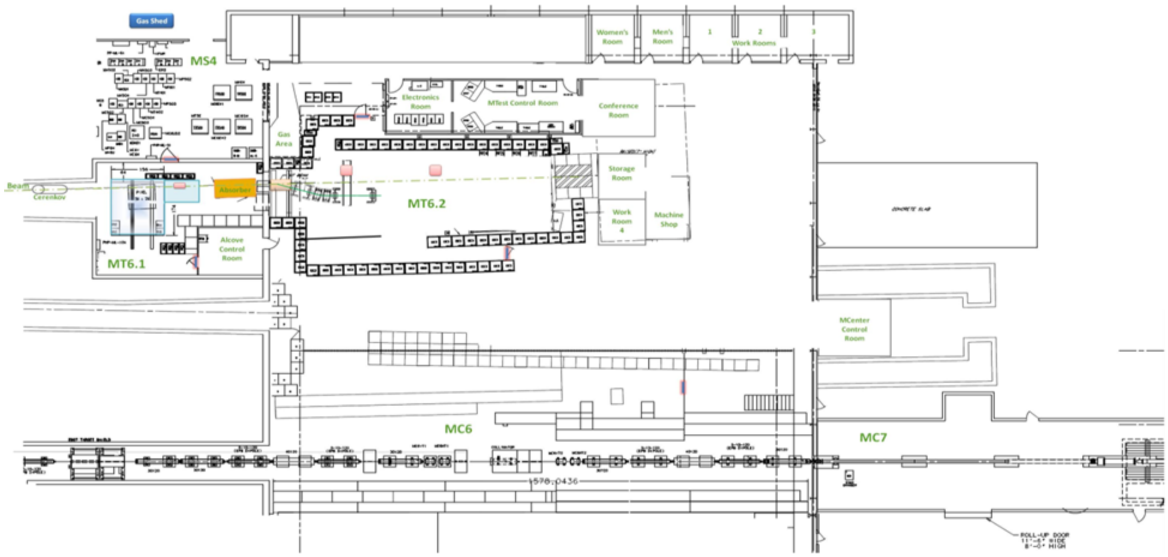

Figure 23. Plan view of the Fermilab Test Beam Facility.

Research Performed at the FTBF in FY 2012

Each test-beam experiment is required to prepare a Memorandum of Understanding with the Laboratory, in which the beam, infrastructure, and safety requirements are spelled out in detail. Three new experiments were approved and took data during FY 2012, and an additional eight experiments returned from previous years to take more data in FY 2012. These eleven experiments are listed in Table II, and represent 229 collaborators from 64 institutions in 14 countries. The chart in Fig. 17 shows the growth in these numbers over the last 5 years.

Table II: Test Beam experiments performed in FY 2011.

Test	Description
T958	FP420 Fast Timing Group
T978	CALICE TEST BEAM
T979	Fast Timing Counters for PSEC
T992	SLHC sensor tests
T1005	Muon g-2 Calorimeter
T1008	SuperB Prototype
T1012	TAUWER Test
T1015	Dual Realout Calorimetry
T1017	CIRTE
T1018	Spacordian
T1019	Belle II iTOP prototype counter

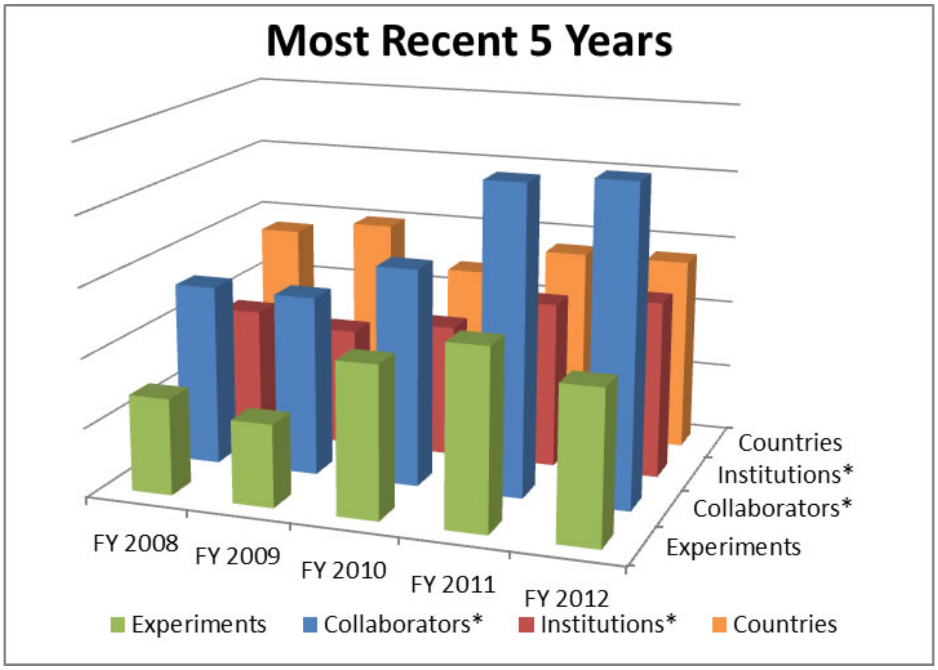

Figure 17: Growth in number of experiments, collaborators, institutions and countries served by the FTBF over the past 5 years. *Number of *Collaborators* has been scaled to fit on plot. *Number of *Institutuions* has been scaled to fit on plot.

The experiments installed equipment or took data 97% of the time for a total of 30 weeks, out of the 30 weeks with beam available during the year, including 9 weeks of double occupancy (two experiments taking data at once). In addition, FTBF hosted a 2 week detector school (EDIT 2012) in mid-February. Weekly facility usage since 2005 (when the facility started taking beam) is shown in Fig. 18.

During the 30 weeks of data taking, a total of 143,849 Fixed Target beam cycles occurred, 103,572 of which had beam, for a total beam sum of 4.30×10^{15} protons, but many of the experiments requested very low intensity running. Until 2012, the Director's guideline for test beam users effect on antiproton production and neutrino beams is 5%, this usually results in one 6 second event in the 60 second timeline for 12 hours a day. However, in 2012 the SeaQuest Experiment started running which was allowed a 10% impact on neutrino beam (one 6 second event /60 seconds for 24 hours a day), and test beam user effects became transparent. Also, due to the ANU Shutdown, there were only 7 months of beam available so the number of pulses adding up to 5% fell dramatically. The chart in Fig. 19 shows the numbers of beam cycles per year over the last 5 years, and depicts how FTBF operations have been well below the 5% impact limit set by the Director.

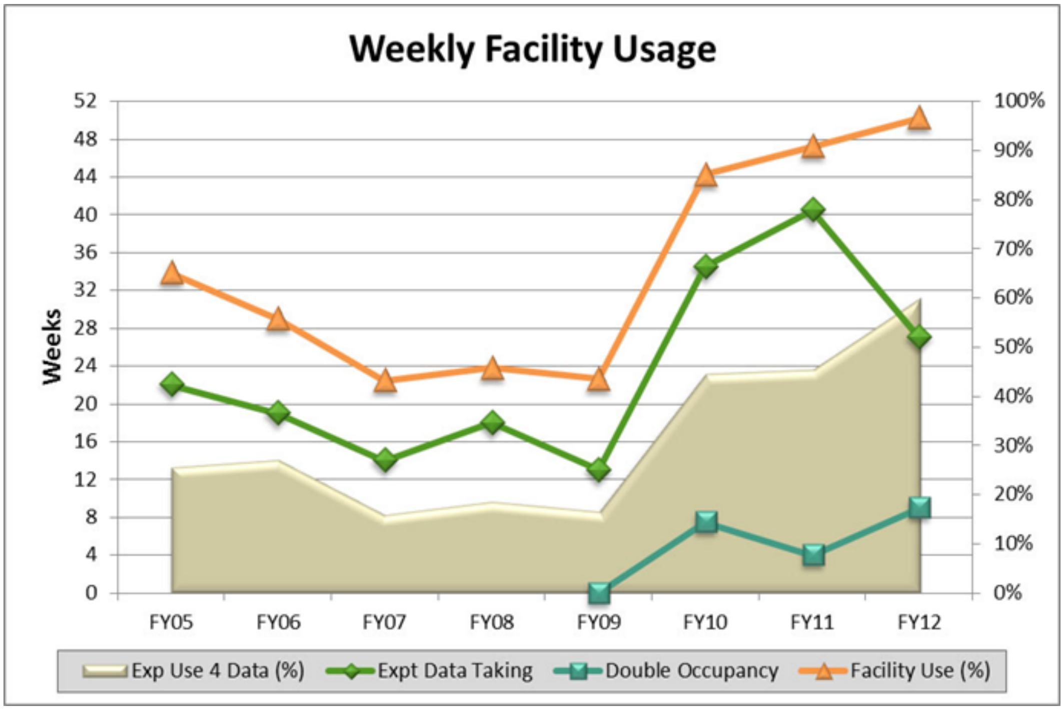

Figure 18: The **Orange Line** is a percentage which includes the number of weeks the facility was being used for data taking by an experiment, and installation of an experiment (some large experiments need several days without beam to install), and beam used for facility tests or outreach (such as EDIT). This total is then normalized to the total number of weeks the beam was available, (less than 52).
The **Green Line** is the number of weeks a year (out of 52) the facility was being used by an experiment to take data.
The **Blue Line** is the number of weeks a year (out of 52) there were two experiments taking data at once.
The gray area is a percentage which sums the total number of experiments (possibly more than1) taking data a week against the number of weeks a year the facility had beam available, (less than 52).

Figure 19: Fixed target pulses, to FTBF with and without beam over the past 5 years